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LITHE PRODUCT MANUFACTURING BY LITHE MANUFACTURING POSSIBILITIES WITH AGENT TECHNOLOGY

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Abstract—Grid Manufacturing (GM) is a new productionparadigm, based upon the use of standardized and modularReconfigurable Manufacturing Systems (RMS). In GM allsystems have a virtual counterpart that actsautonomously, thisincludes both complete manufacturing systems and the products.The control system required for this approach is based upon adistributed and hybrid architecture, using agent technology. Animportant aspect in the paradigm is the product manufacturingdescription. This paper introduces the concept of an architecturewhere the control of the manufacturing is abstracted from theproduct manufacturing blueprint. A product is delineated step bystep by specific services in the grid. The proposed systemincreases flexibility twofold, first by enabling abstraction ofproduct's parts and second by dynamically using manufacturingmeans.

INTRODUCTION

Advances in technology and business strategy havebrought manufacturing paradigms like Agile Manufacturing(AM) [[1]] and Reconfigurable Manufacturing Systems(RMS) [[2]]. In these paradigms, flexibility is the key. Thisincludes multiple aspects, e.g., scalability, modularity, andseveral classifications including process flexibility and volumeflexibility [[3]]. While research in this field is very active,current surveys show that these systems are not widelyadopted by industry [[4],[5]]. Many technical problems stillremain, McFarlane and Bussmann argue that there is a needfor standardization of data exchange, algorithms and architectures [[6]].

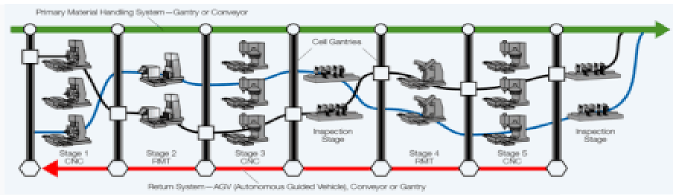
New software paradigms, like agent technology, provideopportunities for use in agile manufacturing. There are manydefinitions of a software agent, we prefer the definition ofWooldridge and Jennings [[7]]: 'An agent is an encapsulatedcomputer system that is situated in some environment and thatis capable of flexible, autonomous action in that environmentin order to meet its design objectives'. What distinguishesagents from normal software, is that agents can autonomouslyinteract with their environment, implying that they can ignorerequests from other software objects if their own designpurpose and beliefs are not satisfied with the requested action.Because of this agents are proficient in working in changing,dynamic environments, so called non-deterministic environments.

Agent platforms do provide more standardization meansfor use in intelligent manufacturing [8]. However, even thisdevelopment has not yet resulted in industrial adoption due toseveral challenges. Quoting from Leitão: 'The majority of agent-based laboratorial control applications use softwareagents without the need of the integration of physical devicesor emulators of the physical devices [5]. Leitão also argues that the industry is not yet adopting agent-basedmanufacturing systems due to several aspects, includingmissing methodologies like integration of physical devices andthe lack of proven technologies. To make agent technologymore acceptable for the industry, it is of importance to look atthe new possibilities that this technology may provide and toresearch and develop prototypes that prove their use inindustry.

This paper discusses how flexibility can be introduced intothe product and manufacturing equipment itself, using anapproach called Grid Manufacturing (GM). A grid, in contrastto a production line, is a group of RMS that have aheterarchical, in contrast to a hierarchical, control system. InGM all systems have a virtual representation based on agenttechnology. This counts for the manufacturing equipment, aswell as the products. Products can be transported dynamicallythroughout the grid and are manufactured by modular andreconfigurable RMS that have been called equiplets[[9]].Products can autonomously negotiate with equiplets in the grid for each prodction step. In this paradigm, equiplets provide generic services, and products deliberate with the equiplets to achieve their goal to bemanufactured. This way manufacturing becomes moredynamic, making it possible to automatically produce uniquely customized products, scale the grid, or reconfigurethe system with limited to no interference with other systems in the grid.

In this paper we will introduce a concept of how a(possibly unique) product manufacturing process is describedand how this product description is automatically delineatedby agent systems through various steps from an abstractproduct description to eventually specific hardwareinstructions.

A **reconfigurable manufacturing system** (**RMS**) is one designed at the outset for rapid change in its structure, as well as its hardware and software components, in order to quickly adjust its production capacity and functionality within a part family in response to sudden market changes or intrinsic system change.[1][2]



A schematic diagram by Rod Hill of a RMS

The RMS, as well as one of its components—the reconfigurable machine tool (RMT)—were invented in 1999 in the Engineering Research Center for

Reconfigurable Manufacturing Systems (ERC/RMS) at the University of Michigan College of Engineering.[3][4] The RMS goal is summarized by the statement: "Exactly the capacity and functionality needed, exactly when needed".

Ideal reconfigurable manufacturing systems possess six core RMS characteristics: modularity, integrability, customized flexibility, scalability, convertibility, and diagnosability.[5][6] A typical RMS will have several of these characteristics, though not necessarily all. When possessing these characteristics, RMS increases the speed of responsiveness of manufacturing systems to unpredicted events, such as sudden market demand changes or unexpected machine failures.. The RMS facilitates a quick production launch of new products, and allows for adjustment of production quantities that might unexpectedly vary. The ideal reconfigurable system provides exactly the functionality and production capacity needed, and can be economically adjusted exactly when needed.[7] These systems are designed and operated according to Koren's RMS principles.

The components of RMS are CNC machines,[8] reconfigurable machine tools,[4][6] reconfigurable inspection machines[9] and material transport systems (such as gantries and conveyors) that connect the machines to form the system. Different arrangements and configurations of these machines will affect the system's productivity.[10] A collection of mathematical tools, which are defined as the RMS science base, may be utilized to maximize system productivity with the smallest possible number of machines. Methodology

Proposed method

The control system required for this approach is based upon adistributed and hybrid architecture, using agent technology. Animportant aspect in the paradigm is the product manufacturingdescription. This paper introduces the concept of an architecturewhere the control of the manufacturing is abstracted from theproduct manufacturing blueprint. A product is delineated step bystep by specific services in the grid. The proposed systemincreases flexibility twofold, first by enabling abstraction ofproduct's parts and second by dynamically using manufacturingmeans.

PRODUCT DESCRIPTION

In classic manufacturing, all parts and manufacturing stepshad to be explicitly defined to be able to automaticallyproduce a product. Customization and replacement of partswere handled before the manufacturing phase. However, asstated in the introduction, with the approach of gridmanufacturing, a product can be manufactured dynamically.Hence, there is the possibility to use product customization inany phase of the manufacturing process. This also opens thedoorto product abstraction. Product abstraction is seen as anexplicit abstraction in the product design. Parts of themanufacturing process can be interpreted by the grid ondemand. For example, different manufacturing hardwaremight be capable of performing a similar service. From thedesign perspective, if a color has not been chosen for theproduct, the grid itself can choose to produce the product withany color based on parameters, like cost or availability ofspecific equipment.

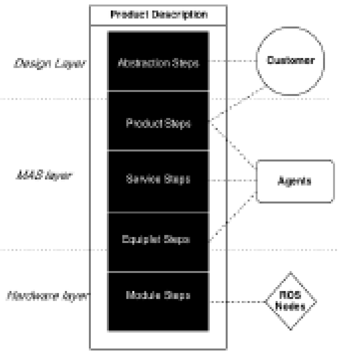


Fig.1.Manufacturing steps from high abstraction to specific machineInstructions

This concept of abstraction can be seen from two differentperspectives: From a design point of view, i.e., the customerdoes not explicitly define the entire product, and from amanufacturing system perspective, product steps can beproduced by a number of different (hardware) systems. Thesystem that will perform a product step is not known a prioriwhen the product manufacturing process is started.A layered model, see **Error! Reference source notfound.**, is used to show which steps are taken to delineate.This product description is based on five levels that each addmore specific information to the required manufacturingprocess. In this model the top layer is most abstract and isbased on the original wishes of the customer, while the bottomlayer consist of the low-level instructions that control each module in the equiplet that will perform the actualmanufacturing steps. In this model the manufacturing processis described by steps, which will need to be translated to thenext level by different systems to come to an explicitinstruction that will be used to control the hardware. The fivesteps are defined as follows:

- The abstraction steps are defined by the customer andexplicitly gives some "don't care" conditions of thedesign that can later be filled in by the grid;
- The product steps are manufacturing steps that describe(without knowledge of the manufacturing systems)how the product should be manufactured. Here the nextstep is already scheduled at a specific equiplet;
- The service steps are the standardized capabilities ofthe grid, which provides its capabilities as a services tothe products. The services are still abstracted from thehardware that performs them;
- The equiplet steps are the result for the translation ofthe service steps to the instructions that are required forthe specific hardware of that equiplet. The service isalways independent of the used hardware;
- Some details that were unknown at the equiplet step layer are filled in at the module steps layer. The modulesteps require runtime information of several modules.

For example, an object location is given from thevision module towards the pick and place module. Inthis final step all instructions become atomic and canbe directly used to control all hardware modules.From a practical perspective the model is divided intothree parts, the design layer, the Multi Agent System (MAS)layer [[11]] and hardware layer. Depending on how explicitthe customer wants to define the product, the design can bemade either within the abstraction or the product step level.The product steps layers can be automatically translated toservice steps,

based on the capabilities of the grid. Once aservice grid step is scheduled to a specific equiplet they can automatically be translated to an equiplet step. These last twotranslations are done by agents within the MAS. However, the equiplet and modules also have a representation that is used todescribe the instructions that will directly control thehardware. This is done by the hardware layer, in the currentsystem this layer is implemented by Robot Operating System
(ROS) [[10]].

III. CASE STUDY-HYBRID ARCHITECTURE

ROS provides specific tools and native code (C++ thatdirectly uses the Operating System, in contrast to most MASplatforms which run in JAVA on a virtual machine) to providegood performance and stability for the direct control of thehardware. ROS also uses a simple kind of 'agents', that arecalled nodes. To test the concept of using multiple levels ofsteps, that are automatically delineated, a hybrid system hasbeen developed using a number of agents and nodes, seeFigure 2. At this level three agents are defined:

• Equiplet agent – Takes care of communication with theproduct;

• Service agent – Uses a knowledge base of all servicesto translate the product into service steps;

• Hardware agent – Has knowledge of the specifichardware and its interfaces of this equiplet and translates the service steps into instructions for thehardware on the ROS layer.

The equiplet steps are handled by nodes in the ROS layer,the final step is not stored on a blackboard, since theinformation of the nodes are directly added to the equiplet step to create the module step. The actor modules are actuators thatrequire instructions, which depend on sensor modules. Thesensor information is used to model the environment and isused for parameters that need to be added to the instructions,e.g., a pick and place command is sent to the ROS layer, butthe location of the part is unknown at that time. However, thevision camera has localized the part that needs to be pickedup. This information of information is stored in theenvironment and is translated to the right coordinates that areused for the actuator. To summarize, the last step is notactually a translation, but consists of adding specificinformation about the environment to the hardware instructionthat will eventually be send to the hardware to actuallyperform the step.

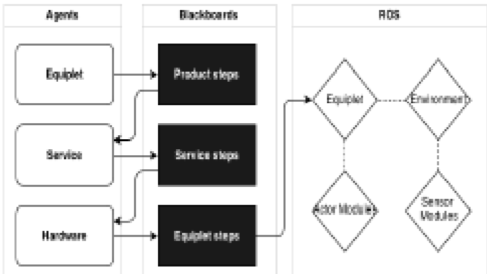


Fig.2. Translations throughout the hybrid architecture

DISCUSSION

The proposed system introduces the possibility toautomatically produce the required steps that are required for adynamic production process in a hierarchical production environment like a grid. The approach to add knowledge toredefine and generate explicit information in a hierarchicalsense was not found in literature for manufacturing. However,a similar approach was introduced successfully for use inknowledge processes in autonomous UAV's .Being able to dynamically create production processes is achallenge, the reconfigurable nature of the systems make itdifficult to design a specific process. The concept that isshown in this paper, makes full use of this heterarchical approach and is ideally suited to be handled by autonomousagents to provide the flexibility and interpret availableknowledge for the necessary translations between all levels.

CONCLUSION

A dynamic description of a manufacturing process forheterarchical and reconfigurable systems is introduced. Themost important impact of this concept is that it becomes easierto handle products that were not designed for specificmanufacturing systems. This provides new opportunities toenable agile manufacturing for industry in the future.

FUTURE WORK

The aim for this paper is to introduce the dynamicmanufacturing concept and describe the systems involved.However, all information concerning the required knowledgeand detailed explanation and implementation of thetranslations between each step level will be published in thenear future.

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